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IGY BULLETIN

A monthly survey by the U. S. National Committee for the International Geophysical Year. Established by and part of the National Academy of Sciences, the Committee is responsible for the U. S. International Geophysical Year program in which several hundred American scientists are participating and many public and private institutions are cooperating.

The ARRL-IGY Propagation Research Project

This report is based on material supplied by Mason P. Southworth, ARRL-IGY Project Supervisior

Long-range, short-wave radio transmissions depend on conditions in the ionosphere, an electrified region of the atmosphere extending from approximately 45 to 250 mi above the earth's surface. The ionosphere contains several semi-permanent ionized layers which reflect most radio waves having wavelengths between 10 m and 10 km. Multiple reflection of a radio signal between ionospheric layers and the earth makes long-distance short-wave transmission possible.

The ionospheric layers are extremely variable with time and space and are extremely sensitive to the mood of the sun. The waxing and waning of solar activity during the eleven-year solar cycle is accompanied by changes in the reflectivity and other characteristics of the ionospheric layers. These changes may cause absorption of signals or propagation in unexpected directions or to unusual distances. They can be studied by analysis of a large number of radio contacts between distant points.

Propagation of radio waves occurs in a variety of ways, or "modes". The following paragraph describes briefly the modes under study in the IGY Propagation Research Program:

Radio waves travelling obliquely through the atmosphere may be scattered from inequalities in the ionosphere (*ionospheric scattering*); this provides transmission to distant points at frequencies for which the ordinary ionospheric reflection mechanism would not function. During sunspot maxima, ionospheric scatter is more extensive under the special ionospheric conditions which then prevail along paths crossing the equator (*transequatorial scatter*). Oblique incidence transmission may also be supported by reflection from clouds or patches of ionization in the E region (*sporadic E*), or by scattering from the long, thin ionization trails produced by meteors (*meteor scatter*). Another form of propagation arises by reflection from irregularities produced during auroras (*auroral reflection*). *Ground backscattering* occurs when a signal reflected from the ionosphere is scattered backward from the earth along the original path. Observation of all these modes of propagation yields information about the state of the ionosphere.

Outline of Program

During the IGY, the radio amateurs of the world are cooperating in recording data on v.h.f. (very high frequency) contacts by all modes of propagation affected by variations in the ionosphere. The US program is directed by the American Radio Relay League, Inc. (ARRL), under sponsorship of the US Air Force's Cambridge Research Center and the National Science Foundation. Large amounts of data are

being gathered for the 50–54 and 144–148 megacycle amateur assignments, along with some information on 70, 220, and 420 mc.

Over 550 amateurs, or radio "hams," representing nearly 50 countries are taking an active part in the program, which is called the ARRL-IGY Propagation Research Project (PRP). They submit semi-monthly reports of the stations they contact or hear by means of the propagation modes described above. Nil reports are filed for intervals when the station is operative but nothing of interest is observed. A few of these stations maintain continuous, or "beacon," transmissions, and thereby give their fellow hams something definite to listen for.

Most amateur stations cannot supply precise quantitative data regarding signal strengths, azimuths, etc. They more than make up for this, however, by their extremely widespread distribution and by their enthusiastic approach, which has permitted amateurs to make the first use of virtually all known types of long-distance propagation. Through their efforts it should be possible to achieve an overall picture of worldwide propagation during the IGY that would be difficult to duplicate by any other means.

Reporting and Recording of Data

The report forms supplied to PRP observers call for: the date and the starting and ending times of the communication; the call sign and location of the other station; a rough idea of the signal's strength and fading rate and the direction from which it comes; the type of propagation the observer feels is responsible; and any pertinent comments. Such reports have been collected continuously since January 1, 1957, and will be collected through the end of the IGY. The six-months-early start served not only as a practice period, but also made it possible for much additional data to be collected as the sunspot cycle approached maximum.

As soon as all or nearly all of the reports for a given period have arrived at the PRP office, each entry on each form is carefully screened and evaluated according to propagation type and type of report. All items surviving this inspection are then transcribed onto special sheets in a partially coded form. Next, the latitude and longitude coordinates of each station (the observer's and the station he contacts or hears) are added to the sheets. To have this information available it has been necessary to maintain an up-to-date file concerning the locations of virtually all the several thousand amateur v.h.f. stations in the world.

At this point, the sheets go to an operator who prepares a punch card for each two-way contact report, heard report, negative report, and beacon report. A punch card presentation was chosen for the PRP data because it lends itself so well to high-speed automatic handling of the large quantities of information being gathered. During the twelve months of 1957, an average of more than 9600 cards per month were required to document the report items. The number will probably be somewhat higher in 1958; card punching and verifying for May has just recently begun. Peak reporting occurs during the early summer months, when sporadic-E propagation on 50 mc is at a high.

Once punched and verified, the cards for each month are put into chronological order and sorted out according to type of propagation. Cards reporting two-way contacts are examined for duplications—that is, two cards may be submitted for one contact when both stations are PRP observers. One card from each such duplicate pair is removed from the file and the other is punched to show it is a "confirmed" report.

At the present time, cards listing negative and beacon reports are being kept on file at the PRP office, while those citing positive results go to the Air Force Cambridge Research Center for further processing. This consists of preparation of a duplicate deck of cards plus the machine-computation of path lengths and midpoint coordinates for the single-hop sporadic-E reports and ionospheric forward-scatter reports. Listings of the single-hop sporadic-E reports are now

being transmitted to the IGY World Data Center as soon as computations for each period are complete.

Another machine program has been evolved for determining the reflection point for auroral propagation, using the locations and antenna headings of the reporting stations. Due to the relatively small number of cases in which heading information is available from both ends of the path, however, this program has not yet been used.

Other Aspects of Program

Other work being done includes the publication of a monthly bulletin, *The PRP News*, which is circulated among the observers. This provides a brief summary of the preceding month's reports as well as other informational and instructional material of interest to radio amateurs. There is also an award system in which observers earn a certificate plus endorsement stamps for consistent reporting.

Further Uses of Data

There are a great many possible uses for this program's data after the IGY. The documentation of auroral and sporadic-E conditions has been particularly complete and should be of great value in investigations of these phenomena. In the case of transequatorial-scatter propagation, PRP reports have even more potential worth. Not only has much information been gathered for the Central and South American paths first noted by amateurs during the last sunspot maximum, but similar work has been done for the first time between Japan and Australia and between southern Europe and the Rhodesias. These additional circuits should help provide an insight into the seeming location selectivity of transequatorial propagation.

IGY stations operating in Chile and Peru under the direction of the National Bureau of Standard's Central Radio Propagation Laboratory have been of special help. These have been monitored by the amateur observers, and have been received in the United States and southern Canada with surprising consistency and with surprisingly variable fading and strength characteristics during the equinoctial periods.

Although punch cards have not been prepared for the F2-skip reports, they, together with the backscatter data, should furnish the actual highest usable frequencies over many varying paths for comparison with the predicted values and with those observed by other means.

The work of the hams has proved its worth many times in the past. It is expected that the ARRL-IGY Propagation Research Project will help fill a gap by making a large volume of amateur reports available to investigators in an easily usable form.

Weather at US-IGY Antarctic Stations During 1957

The following material was supplied by Edwin C. Flowers, meteorologist, US Weather Bureau.

The year 1957 was the first complete year of operation for most of the United States IGY stations in Antarctica. It was also the first year in history during which enough meteorological stations were in operation to give a synoptic picture of Antarctic weather.

Although it is much too early to answer the fundamental meteorological questions posed by the Antarctic environment, the observations made at US stations recorded facts about Antarctic surface and upper-air weather that had never before been docu-

mented. Highlights of the weather observations at each of the stations are given below.

IGY Little America Station

At IGY Little America Station, the year 1957 was warmer than any of the five previous years for which records are available (Table 1).

The extreme cold temperature recorded during 1957 (−53°C) was also considerably warmer than the absolute minimum over the period of record (−61°C), observed in 1956.

The past year was one of striking weather changes. Storms in June (a mid-winter month) gave that month an unusually warm average temperature. Thus, the June average of −23.9°C made it the warmest month since February. It was 7° warmer than May and nearly 12° warmer than July (see Fig. 1). The most sustained storm in June lasted, nearly without interruption, from the 13th through the 21st. On the 14th, the average wind speed for the day was 42 mph, with an average temperature of −8°C. The peak gust was 59 mph. As in nearly every case of strong winds at Little America Station the wind direction was from the NNE. During the stormy period, the temperatures rose rapidly with the increase in wind speed. Prior to the commencement of the storm, the minimum temperature was −46°C, while during the period June 13–21, the maximum temperature was −4°C and the minimum was −23°C. On the day following the cessation of the extreme winds, the temperature dipped to a minimum of −32°C.

This pattern of warming temperatures with strong winds is a normal feature in the Antarctic due primarily to mixing of the air in the inversion layer. The inversion layer consists of a stratum of air, from the surface to perhaps 500 m to 1000 m above the surface, throughout which the temperature rises with increasing altitude. At Little America Station in winter, the top of the inversion may be as much as 10–25°C warmer than the air next to the surface. An increase in wind speed in this layer causes turbulent mixing and a subsequent warming of the near-surface air.

Table 1. *Little America (and Framheim,* 1911): Average Annual Temperatures (°C)*

1911	1929	1934	1940	1956	1957
−27.2	−26.4	−25.7	−26.2	−25.1	−24.2

* Amundsen's camp. Near the present location of Little America Station.

The absolute minimum temperature for the year (−53.0°C) was recorded on May 24. The month of May also produced the warmest temperature ever recorded for that month (−1.0°C on the 11th). This was the greatest temperature spread for any month in 1957.

The average wind speed for the period April-September was 15 mph, while for the remaining six months the average was 12.5 mph. The sea-level pressure ranged from a high of 1030 mb on June 10 to a low of 931 mb on August 29. From January 30 through December 31, a total of 644 rawinsonde flights were made. The average height during the months April-September was 18.8 km; for the remaining months it was 21.3 km.

IGY Byrd Station

Nearly continuous storminess was the significant feature of the weather at Byrd Station during July, August, and September, 1957. These three months had average wind speeds of 22, 27, and 26 mph respectively. During August, ten days had daily average speeds greater than 30 mph and six days had average speeds greater than 40 mph, while only two days had average speeds less than 15 mph. Nearly all of the strong winds came from a northerly direction, usually with an easterly component. During most of the periods of storminess, the northerly winds were consistent throughout the troposphere above Byrd Station. They usually reached near jet velocities between 8 and 10 km above sea level. With strong winds, blowing snow becomes a hazard. During

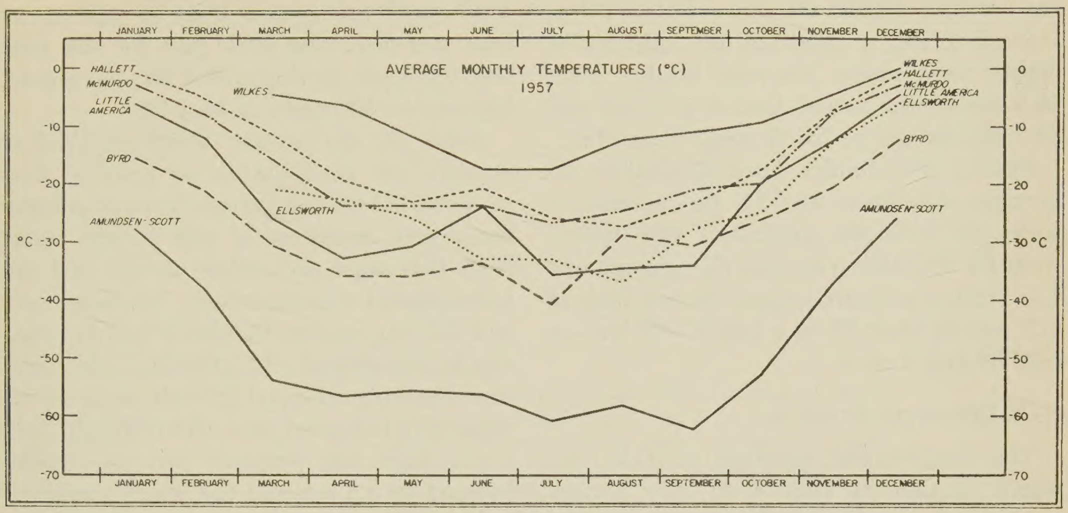

Fig. 1. *Average Monthly Temperatures for US-IGY Antarctic Stations and the Air Facility at McMurdo Sound During 1957.*

August, visibility was reduced to a quarter of a mile or less for this reason on four out of five days.

Despite the high incidence of strong winds, the station maintained an excellent record of rawinsonde flights. From March 23 through December 31, a total of 510 rawinsonde flights were made. Average heights were 16.4 km for the period April-September and 22.7 km for the period October-December. As at other high latitude Antarctic stations, minimum stratospheric temperatures in the range of −80°C to −90°C were a feature of the upper atmosphere during the three winter months. The yearly range of station pressures for 1957 was from a high of 833 mb on May 13 to a low of 775 mb on July 30 and December 9.

IGY Amundsen-Scott Station

Quite different weather prevailed at the Pole Station, where only one significant storm was observed. This occurred May 25–29, with wind speeds in the range of 25–50 mph. With the onset of this storm, the temerature rose from −69°C, with a 14-mph wind, at 0900 GCT to −46°C, with a 40-mph wind, 24 hours later. Only a few gusts greater than 40 mph were observed during the remainder of the year. However, winds of moderate speed prevailed nearly constantly throughout the winter months, producing for the period April-September an average speed of 18 mph. During June, of the 720 hourly wind speeds measured, 95% were in the range of 13–29 mph; of the remaining 5% of the hourly records, 4% were in the range 7–12 mph and 1% greater than 30 mph. No hourly winds of less than 7 mph were recorded during the month. The peak gust for the year was 54 mph, measured on May 25.

Throughout the winter, the surface inversion averaged 25°–30°C, with the top in the vicinity of 500 m above the surface. An extreme inversion of 41°C within 700 m occurred at 0600 GCT on September 18.

With the return of the sun, rawinsonde observations began to give indications of a rapid warming in the stratosphere. At 25 km, temperatures rose from −67°C to −24°C from the 1st to the 30th of October. This warming gradually became apparent in the troposphere, so that by mid-December miniumum temperatures measured in the upper air were in the range −45° to —50°C. The lowest temperature measured in the stratosphere was −91.2°C at 17.7 km above

sea level on August 20. From March 27 to December 31, a total of 541 rawinsonde flights were made. Average heights were 16.9 km for the period April-September and 21.2 km for the period October-December.

During the months April-September the average cloudiness was 2.6 (on a scale in which 10 indicates maximum sky cover), while for the other 6 months the average was 4.7. Station pressure ranged from a high of 713 mb on May 27 to a low of 657 mb on July 30 and August 1.

IGY Ellsworth Station

The temperatures observed at IGY Ellsworth Station in 1957 were very similar to those observed at Little America Station as far as averages and extremes are concerned. The absolute minimum temperature for 1957 (−53.3°C) occurred on May 10. It is of interest to note that the synoptic weather situation that produced the Ellsworth Station minimum was at the same time bringing record cold (−73.6°C) to the Amundsen-Scott Station and record warm temperatures to Little America Station (−1°C) and to Byrd Station (−6.9°C).

The average wind speed for the months April-September was 14 mph; the prevailing wind direction was south for 5 of the 6 months. For the remaining 6 months, the average speed was 10 mph, also prevailing from the south. The peak gust for the year of 63 mph occurred on May 24. High and low station pressures for the year were 1014 mb on August 10, and 957 mb, on July 22. Between April 1 and December 31, a total of 496 rawinsonde flights were made.

IGY Wilkes Station

Wilkes Station experienced the warmest climate of the seven United States stations and, although not the windiest as far as averages go, it had the highest incidence rate for gale-force winds. In the month of August, wind speeds exceeded 58 mph on 13 days, although the average speed for the month was only 15 mph. During each of the 10 months of record for 1957, the wind speed was greater than 55 mph on at least one day. The peak gust for the year was 105 mph, on September 30; the second highest was 100 mph, on May 28.

Some of the strong winds at Wilkes Station are attributable to gravity flow of air off the nearby ice cap. The commencement and cessation of the strong winds from this cause are rather abrupt and are accompanied simultaneously by large rises and falls in pressure. October 9 was a typical day in this respect. At 1500 GCT the pressure suddenly dropped 2.5 mb, with an increase in wind speed from 10 to 50 mph. Two hours later the pressure just as rapidly jumped up 3.5 mb and the winds slackened to 10 mph. Although the prevailing winds are ESE (off the ice cap), the gravity flow only occasionally reaches these extreme speeds. Apparently, the location and height of the surface inversion with respect to the station is an important factor in the incidence of these strong winds.

During the month of December, rawinsonde flights at Wilkes Station were as follows: Of the total of 61 flights made during the month, 60 reached or exceeded the 50-mb pressure level (20.6 km above sea level); moreover, 56 of these reached or exceeded the 25-mb pressure level (25.6 km above sea level). The average termination height for this month was 26,992 m.

The minimum temperature for the year (−33°C) was recorded on July 24. For each month, with the exception of July and September, the maximum temperature reached 0°C or higher. The sea-level pressure ranged from a high of 1019 mb, on May 23, to a low of 951 mb, on September 10.

An ice-cap station, some 50 mi ESE of the main camp and at an elevation of about 1310 m, provided additional meteorological data for this region. At the ice-cap station, temperatures averaged about 10°C lower than those at the main camp. The minimum temperature of −48.2°C was measured on June 14. The average wind speed was about 25 mph, with a prevailing wind direction of ESE.

Table 2. *Averages and Extremes of Temperatures at US-IGY Antarctic Stations in 1957*

Station	Temperatures (°C) and Dates		
	Average	Max.	Min.
Little America	−24.2	+4.4 Jan. 3	−53.0 May 24
Byrd*	−27.6	−4.4 Nov. 29 Dec. 26	−56.9 June 11
Amundsen-Scott*	−48.7	−18.9 Dec. 15	−74.5 Sept. 17
Ellsworth*	−22.3	+1.8 Nov. 25	−53.3 May 10
Wilkes*	−8.1	+6 Dec. 20 Dec. 21	−33 July 24
Hallett*	−15.1	+4.0 Dec. 13	−42.0 Aug. 3
NAF McMurdo*	−16.7	+3.4 Dec. 23	−41.1 Aug. 2

* New extremes recorded during 1958, as follows:

Byrd	minimum temperature −59.7 on June 16, 1958
Amundsen-Scott	maximum temperature −14.7 on Jan. 12, 1958
Ellsworth	minimum temperature −55.6 on May 13, 1958
Wilkes	maximum temperature +8 in Jan. 1958
Hallett	maximum temperature +5.7 on Jan. 15, 1958
McMurdo	maximum temperature +4.4 on Feb. 4, 1958

IGY Hallett Station

Low-pressure systems moving past the station on their way into the Ross Sea area provided the Hallett Station with its most interesting weather. The annual temperature regime, with respect to monthly averages, was very similar to that observed at many other Antarctic stations, with a rapid drop in April and May, followed by warming in June, and another minimum in July and August.

The average wind speed for the months April-September was 9 mph; for the other 6 months the average was 10 mph. Prevailing direction was SW for 7 months and SSW for the other 5 months. The maximum gust measured was 114 mph, on October 23; two other months had days with wind speeds in excess of 85 mph. The storm of mid-October, which produced the 114 mph gust, interrupted a continuous series of 246 rawinsonde flights begun on June 23. The sea-level pressure ranged from a high of 1027 mb, on May 28, to a low of 955 mb, on July 23.

NAF McMurdo

The Naval Air Facility, at the foot of Observation Hill on Ross Island, McMurdo Sound, had its share of blizzard weather. During each month from May through November, maximum wind speeds of 65 mph or greater were recorded on at least one day. May had a peak gust of 96 mph, while a peak of 97 mph was measured in June. The average temperature for the months April-September was −23.9°C; the other 6 months had an average of −9.4°C. The sea-level pressure ranged from an absolute high for 1957 of 1041 mb, in May, to a low of 949 mb, in August.

During the period April-December 1957, 68% of the scheduled rawinsonde observations reached or exceeded the 50-mb pressure level and 19% reached or exceeded the 25-mb level. During September 1957, 51 observations (or 85%) reached or exceeded the 50-mb pressure level; 21 observations (or 35%) reached or exceeded the 25-mb level.

Table 2 lists the annual average temperatures and extremes during 1957 for the seven US-IGY stations (including the joint New Zealand-US Hallett Station). For the Wilkes and Ellsworth Stations, the period used to compute the annual average was March 1957 through February 1958. Figure 1 is a plot of the average monthly temperatures (°C) for the same seven stations.

Fourth US-IGY Satellite

The fourth US-IGY scientific earth satellite, 1958 Epsilon, was launched in a northeasterly direction from Cape Canaveral, Florida, a few seconds after 11:00 am EDT July 26, 1958. A little more than six minutes later the satellite, also known as Explorer IV, entered into an orbit which will cover an area between 51°N and 51°S latitude (see Fig. 2), as compared with approximately 34° for 1958 Alpha and Gamma. The launching vehicle was identical to those used for 1958 Alpha and Gamma except for an increase in thrust in the high-speed upper stages; the vehicle was developed jointly by the US Army Ballistic Missile Agency and the California Institute of Technology's Jet Propulsion Laboratory.

Satellite Characteristics: The steel satellite is 80 inches long, 6 inches in diameter, and weighs 38.43 lbs, about 7½ lbs heavier than its predecessors. Like 1958 Gamma, it does *not* carry a turnstile antenna with its four whip-like extensions; 1958 Epsilon's two dipole antennas utilize the skin of the satellite itself.

Instrumentation: 1958 Epsilon carries two Geiger-Mueller counters and two scintillation counters designed to measure corpuscular radiation at several levels of intensity. 1958 Epsilon's total concentration on corpuscular radiation studies was prompted by data obtained from the earlier Explorer satellites. This had suggested the existence of radiation of a very high intensity at altitudes greater than about 1000 km (about 600 mi).

The instrumentation on 1958 Epsilon was designed and developed by Carl E. McIlwain and George H. Ludwig of the State University of Iowa, under the direction of James A. Van Allen, head of SUI's Physics Department. The four detectors were developed by McIlwain, and are linked to an electronic system of measuring, scaling, and amplifying devices; the overall scientific package was engineered by Ludwig.

One of the Geiger-Mueller counters, shielded with 1/16 of an inch of lead, measures absorption of X-radiation and counts intensities of the more penetrating cosmic

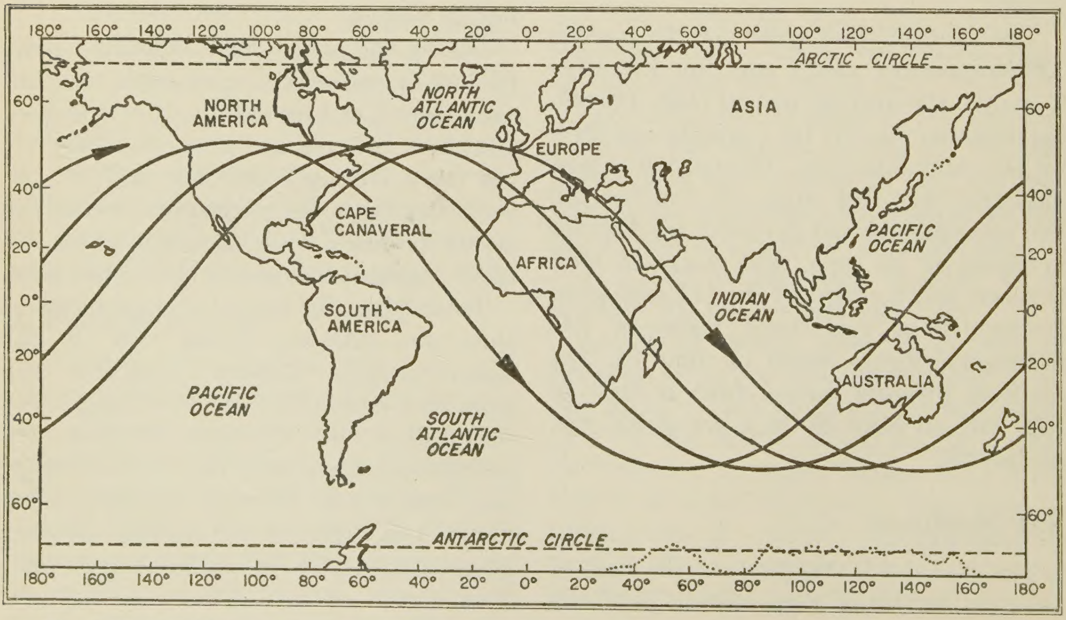

Fig. 2. *Path of 1958 Epsilon During First Four Circuits of the Earth, on July 26, 1958. US Army.*

rays. The other counter has been scaled to handle some 1500 times the radiation intensity that caused the detection and scaling systems of 1958 Alpha and Gamma to blank out (see *Bulletin No. 13, July 1958*).

Scintillation counters use crystals of selected materials mounted directly on the faces of sensitive photoelectric cells, usually of photomultiplier type. The scintillators emit flashes of light when radiation passes through them. The resulting light pulses are converted into electric pulses by the photomultiplier.

One scintillation detector in Explorer IV makes use of a lightly-aluminized crystal of cesium-iodide as a scintillator. The integrated electric current from its photomultiplier provides an approximate measure of the total energy of the incident corpuscular radiation. A second scintillation detector utilizes an aluminized plastic scintillator and acts as a counter of incident corpuscular radiation.

1958 Epsilon carries two radio transmitters. The low-power transmitter operates on 108.00 megacycles at 10 milliwatts, the high-power transmitter on 108.03 mc at 30 mw. The battery life for each is expected to be about two months. Both transmitters broadcast the same five channels of telemetered information continuously, although the low-power transmitter is primarily for tracking purposes.

Tracking: Besides the Naval Research Laboratory's usual Minitrack network (see *Bulletin No. 2*), ten Microlock stations are tracking the satellite and recording its telemetered data. The stations are located at Cape Canaveral, Florida (JPL); Fort Monmouth, N. J. (Army Signal Corps); Van Buren, Maine (Army Signal Corps); Aberdeen Proving Ground, Md. (Ballistic Research Laboratories); White Sands, N. M. (BRL and JPL); Cedar Rapids, Iowa (Collins Radio Company); Temple City, Cal. (San Gabriel Valley Radio Club); China Lake, Cal. (Naval Ordnance Test Station); and Goldstone Test Station, Camp Irwin, Cal. (JPL).

The first precision photograph of the satellite was secured by the Baker-Nunn satellite tracking camera at Arequipa, Peru, at 12:53 am Universal Time, July 28, 1958. More than 230 Moonwatch teams were also in action. The first visual sightings of 1958 Epsilon by a Moonwatch team took place in Pretoria, Union of South Africa, at 3:20 am UT, July 29, 1958. The satellite was sighted by Roy Smith, who heads the Pretoria team.

Orbit: The Naval Research Laboratory reported the orbit of 1958 Epsilon, as of July 29, 1958, as: Period, 110.224 minutes; inclination of orbit to the equator, 50.13°; perigee, 157.3 statute mi; apogee, 1379.8 statute mi; velocity at perigee, 18,406 mph; and velocity at apogee, 14,232 mph.

Early Results

Preliminary results from about one-fourth of 1958 Epsilon's first 200 passes have been reported by State University of Iowa staff. They indicate that the intense radiation measured by 1958 Alpha and 1958 Gamma is not X-radiation originating within the satellite through bombardment of the satellite's skin by solar electrons, as believed at first. The data show, instead, that the Geiger-Mueller and scintillation counters in the satellite are being struck directly by high-energy charged particles, probably electrons. These may include hydrogen protons or other atomic fragments that have lost some of their electrons.

At least 60% of the charged particles readily penetrate the lead shielding one of the satellite's geiger tubes. The radiation intensity appears to double with each 60 mi above 250 mi., at least to Explorer IV's maximum altitude. According to SUI physicists, the satellite has found a radiation level of about 10 roentgens/hr at a height of 1200 mi above South America. This is more than 100 times the saturation level of the geiger tube in 1958 Gamma.

Cosmic Ray Program: First Twelve Months

This report is based on a summary of results in the IGY Cosmic Ray Program prepared by Scott E. Forbush, Department of Terrestrial Magnetism, Carnegie Institution of Washington.

Cosmic rays are extremely high-energy electrically-charged particles that continually bombard the earth from all directions. They attain their high energies—ranging from about 100 million to 10 billion billion electron volts (10^8 to 10^{19} ev)—within our galaxy. On rare occasions, our sun also produces charged particles with cosmic ray energies that reach the earth.

The primary cosmic rays reaching the earth's atmosphere consist almost entirely of protons (approximately 90%) and heavier nuclei. Their interaction with atmospheric particles creates "showers" of secondary particles. These include secondary protons and nucleons, pi mesons (charged and neutral), and heavier mesons.

Neutral pi mesons disintegrate into two gamma rays; these are ultimately transformed into electrons and photons and contribute to the soft (low-energy) component of cosmic rays. At surface level, this contribution to the low-energy component is small.

Charged pi mesons commonly disintegrate, forming charged mu mesons. The charged pi mesons that do not have time to decay before interaction with the atmosphere may cause new electron-nuclear showers, or nuclear fission disintegrations of the star type observed in emulsions.

Charged mu mesons constitute the high-energy, or hard, component of cosmic rays. Changes in intensity of the charged mu mesons are measured by heavily shielded ionization chambers and by heavily shielded counters.

Neutron monitors, on the other hand, are more sensitive to variations arising from changes in the intensity of the much lower energy primaries. For example, they indicate a latitude variation ten or more times greater than measured by shielded ionization chambers. In a neutron monitor, the cascade of atmospheric nucleons generates neutrons locally in the lead of a lead-paraffin pile. The paraffin slows down these neutrons to thermal energies; this increases the probability that they will be captured by the Boron-10 nuclei in the $B^{10}F_3$ gas used in the counter. After capture, the Boron-10 disintegrates into a lithium nucleus and an alpha particle. The 2.5 mev energy of these particles produces a pulse of ionization to trigger the counting circuit.

The fact that the IGY was scheduled for a period of maximum solar activity is of particular benefit to cosmic ray research. A number of significant advances have already been made in our understanding of cosmic rays and their causes, effects, and interrelationships with other phenomena. The following is a summary of some advances in cosmic ray knowledge by US investigators through the first 12 months of IGY.

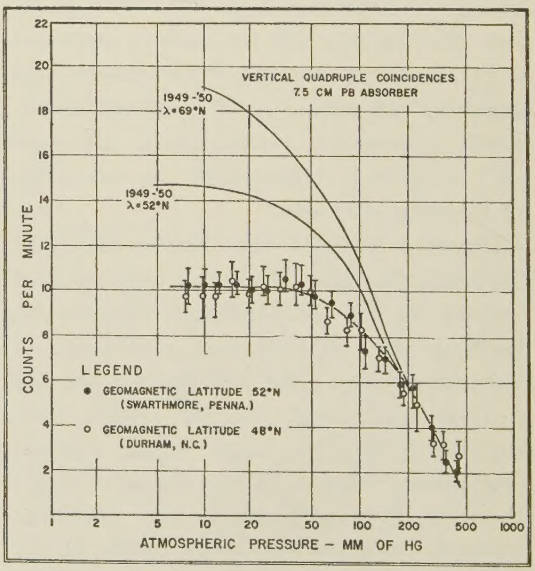

Fig. 3. *Variation of Cosmic Ray Counting Rates With Height at Geomagnetic Latitudes 52°N and 48°N. Data for geomagnetic latitude 52°N were gathered on three separate balloon flights; data for 48°N were gathered on four flights.*

Variations with the Solar Cycle

IGY scientists, using a variety of techniques, find that the beam of cosmic ray particles coming principally from the galaxy and arriving at the earth has drastically changed between the last minimum of solar activity (1954) and the present solar maximum (1957–58).

Mu-Meson Intensity: S. E. Forbush of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, is supervising a long-term experiment involving continuous registration in ionization chambers of the mu-meson component of cosmic radiation. This work has continued over a period of two solar cycles and the records represent the longest continuous chain of cosmic ray data published. The results show an 11-year cycle of intensity variations roughly opposite in phase to that of sunspot numbers, but lagging about one year behind the sunspot numbers. Since the IGY is near a peak in the solar activity cycle, cosmic ray intensity is now relatively low.

The range of this variation in terms of monthly means is about 6%, as measured at Cheltenham, England; Huancayo, Peru; Christchurch, New Zealand; and Godhavn, Greenland. The variability of daily means from monthly means for 1957 was considerably greater than during the two previous sunspot maxima. Study of these variations in the mu-meson component of cosmic rays provides information on changes in the flux of relatively high-energy primaries.

Neutron Intensity: The solar-cycle variation is also exemplified by measurements made between 1954–55 and the first part of 1958 by J. A. Simpson and his colleagues of the University of Chicago. They found a decrease of 25% in neutron intensity at Climax, Colorado. They also showed that the ratio of neutron intensity at Climax to that at Huancayo decreased from about 1.25 in 1954 to about 1.08 in 1958, thus demonstrating a strong energy dependence on the 11-year intensity variation. Latitude surveys with neutron equipment in aircraft showed the proton integral-energy spectrum to be about E^{-2} in 1948 and in 1958, and about $E^{-2.7}$ in 1954. (The observed flux of particles arriving is proportional to the particle kinetic energy, E, raised to the indicated power.) On the basis of balloon flights between 1953 and 1958 it was shown that the 25% decrease in neutron intensity at Climax represents more than a twofold decrease between 1954 and 1958 for particles with energies of 1 bev or greater.

Ionization: IGY balloon flights carrying ionization chambers were made in 1957 at Thule under the direction of H. V. Neher, of the California Institute of Technology (see *Bulletin No. 11*). It was found that the ionization at an atmospheric pressure level of 15 gm/cm² (93,500 ft) was only half that in 1954, and that the number of primary particles had diminished by a factor of four. Similar observations at Thule in 1955 and 1956 showed that the intensity decrease followed closely an increase in sunspot numbers.

Vertical Particle Flux: A series of balloon soundings were made by J. R. Winckler and L. Peterson of the University of Minnesota in August-September 1955 at geomagnetic latitude 51.2°N to 64.2°N, and IGY flights were conducted at geomagnetic latitudes near 51.2°, 55.3°, and 58.6°N in June 1957, immediately prior to the beginning of the IGY. It was found that near the sunspot maximum in 1957–58 the vertical particle flux had decreased at all atmospheric levels greater than 300 gm/cm² (33,000 ft). It was also found that the magnitude of this decrease became greater with increasing height until, at high altitude and high latitude, it reached nearly a factor of two. These experiments showed that of the additional particles admitted at 10 gm/cm² (102,000 ft) in 1955 between geomagnetic latitudes 51.2°N and 58.6°N, at most only one-sixth remained in 1957, and that the relative latitude effect in this range was reduced from 40% to 10% or less.

Latitude Knee: With simultaneous balloon flights at geomagnetic latitudes 48°N and

52°N, near May 1, 1958, M. A. Pomerantz of the Bartol Research Foundation showed the variation with atmospheric height of the vertical quadruple-coincidence counting rate to be the same at both latitudes (see Fig. 3). (A quadruple-coincidence instrument is one that records the passage of those cosmic ray particles which trigger four separate, successive counters, thus indicating the angle of entry of the particle.) This indicated that the "knee" of the latitude effect—the latitude at which cosmic ray intensity ceases to increase with increasing latitude, represented graphically by a bend, or "knee," in the curve—was then south of 48°N. Similar observations in 1949–1950 showed no evidence of a true primary knee south of geomagnetic latitude 60°N.

Nucleonic Component: John A. Lockwood, of the University of New Hampshire, reports that from July 1954 to December 1957 the monthly mean intensity of the nucleonic component of cosmic radiation measured at Mt. Washington, New Hampshire—geographic latitude 44.2°N, elevation 6262 ft—decreased by 22%. The lowered intensity now prevailing came about through a series of sudden decreases. The largest of these occurred in February and November, 1956, and in January and September, 1957. After these decreases, the intensity recovered only partially. This long-term variation was accompanied by an increased number of day-to-day intensity changes.

Rapid Decreases During Magnetic Storms

During the past several years, it has become clear through the work of US investigators that the intensity of the cosmic radiation reaching the earth undergoes large changes with time, and that these changes are associated with electromagnetic phenomena on the sun. Phenomena that produce large changes in the cosmic ray intensity at the earth have become the central problem of interest. Not only does their study add to an understanding of cosmic ray and solar effects, but analysis of this data is leading to knowledge of magnetic fields in interplanetary space and to explanation of many magnetic storm effects at the earth's surface.

In 1957, large decreases in cosmic-ray intensity during magnetic storms were unusually numerous. Several US investigators have recorded large variations in daily mean neutron intensity for various intervals during the IGY. The sudden decrease in daily mean neutron intensity from August 29 to 30, 1957, was between 8% and 10% at IGY stations operated by the Universities of California and Chicago and the Bartol Research Foundation, Pennsylvania. This is about 2.5 times the change in ionization at Huancayo.

R. B. Brode, University of California, has reported daily means of neutron intensity at Berkeley and Hawaii for the period July 1, 1957–March 31, 1958. There is a good correlation between variations at these stations; variations are smaller at Hawaii, however, undoubtedly owing to the difference in geomagnetic latitude (see Fig. 4).

M. A. Pomerantz, Bartol Research Foundation, reports that values of daily means of neutron intensity at Thule (August 20, 1957–March 31, 1958) correlate well with values obtained by D. C. Rose at Ottawa and Resolute, Canada. Using balloons on several days between August 21 and September 18, 1957, Pomerantz also measured the vertical quadruple-coincidence rate under 7.5 cm Pb at altitudes above the 28 gm/cm^2 (80,000 ft) pressure level. These results show a decrease of about 20% near September 1 as compared with August 20.

Twelve-hour neutron-intensity means at Chicago from July 22 to September 1957 reported by Peter Meyer showed a range of nearly 20%. Meyer has also conducted balloon flights in Canada on days when the neutron intensity at Chicago differed, from one to another of these days, by 12%. His purpose was to determine whether the change in proton and alpha-particle flux is different at these two locations.

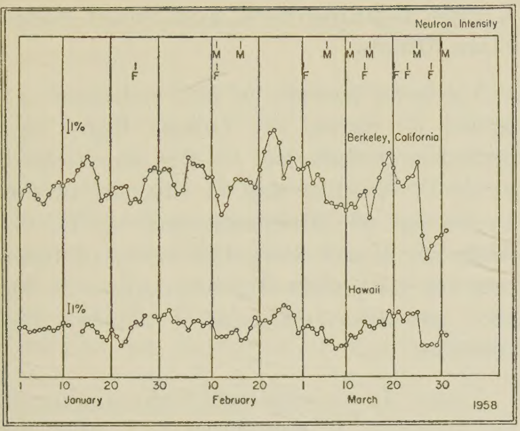

Fig. 4. *Comparison of Daily Means of Neutron Intensity at Berkeley, California, With Daily Means at Hawaii.* (*M = magnetic storm; F = solar flare*)

Flux of Alpha Particles and Heavy Particles

Investigation of the flux of the alpha-particle and heavy-particle components of cosmic rays is providing additional knowledge of the time scale of fluctuations of cosmic rays, their behavior at higher energy levels, and the variation of the heavier charge components of the primary particles with respect to solar activity.

Alpha-Particle Flux: P. S. Freier, E. P. Ney, and C. J. Waddington, of the University of Minnesota, report several determinations of the flux of primary cosmic ray alpha particles made during the past few years at high altitudes over Minnesota and over Texas. In an appreciable number of these determinations, small stacks of nuclear emulsions were carried aloft by balloons for use as detectors.

In such a flight made just prior to the IGY, Freier and Ney found that the flux over Minneapolis had fallen from its previous value of about 280 alpha particles/$m^2 \cdot$ster$\cdot$sec (the number of particles passing through a one-square-meter area each second from directions lying within a unit solid angle, or steradian) to a value a little more than half that. A flux value of 138 ± 9 alpha particles/$m^2 \cdot$ster$\cdot$sec was determined; another stack, exposed at the same place some 3½ months later, indicated that this decrease was not a transient effect.

The latter flight was made during a large Forbush decrease. While there does not appear to have been a significant difference between the total fluxes observed in the two stacks, there was a significant reduction of low-energy particles. In the first stack, the flux of alpha particles with energies below 700 mev/nucleon was 47 ± 8/$m^2 \cdot$ster$\cdot$sec (the old value was 120 ± 10), while in the second stack it had fallen to approximately one-half this value.

Yet another flight made about 1½ months later over Texas, where the cut-off energy is approximately 1.5 bev/nucleon, showed that the flux of these high-energy particles had declined by about one-third from the previously measured value of 97 ± 8/$m^2 \cdot$ster$\cdot$sec.

In each of these stacks, the energies of the low-energy alpha particles were determined from a measurement of their ionization, using a photodensitometer.

In addition to the ionization measurements, energy determinations were made from multiple-scattering measurements on about half the alpha particles observed in the second stack exposed over Minnesota. These suggest that the present integral-energy spectrum is not as steep as it was previously, and that the new flux obtained over Texas agrees closely with that predicted from the Minnesota measurements.

H. Yagoda has reported measurements of the time variation of the omnidirectional flux of heavy primaries, as obtained by small emulsion blocks exposed in rockets at geomagnetic latitude 41°N between December 1952 and October 1957. The experiments were carried out with the cooperation of GRD-AFCRC. They show a 10–20% diminution in intensity roughly coincident with a period of maximum sunspot activity, in 1957 (see Fig. 5). The small effect at low geomagnetic latitudes parallels more pronounced variations both in the total ionization and in the alpha-particle

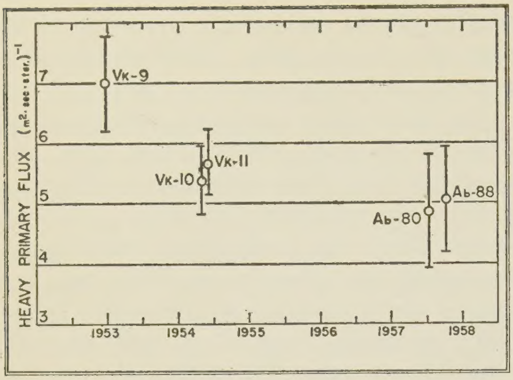

Fig. 5. *Decrease in Omnidirectional Flux of Heavy Primaries, 1952–58, at Geomagnetic Latitude 41°N. Vk numbers represent flights using Viking rockets; Ab numbers, Aerobee flights.*

flux at geomagnetic latitude 55°N during the same period, as indicated by exposure of emulsions near maximum balloon altitudes (about 100,000 ft). Yagoda suggests that the heavy primary component of the cosmic radiation follows time variations related to the solar cycle.

Proton and Alpha-Particle Time Variations: Using a simplified combined scintillation and Cerenkov counter on balloon flights over Prince Albert, Canada, the time variation of the protons and alpha particles was measured separately by Peter Meyer of the University of Chicago. A detailed analysis has been completed only for the flights on August 30 and September 16, 1957. While the neutron intensity at Climax was 12% greater on the latter date than on the former, the proton intensity over Prince Albert was 16% greater and the alpha-particle intensity 25% greater. Meyer feels that these results are consistent with a common modulating mechanism for protons and alpha particles. On both flights, the alpha-particle flux seemed to increase appreciably during the eight hours the equipment was at altitude without a corresponding change in proton intensity. These independent changes in alpha-particle and proton intensity cannot be accounted for by any modulation mechanism so far considered.

X-rays, Gamma-rays, and Small Solar Flare Effects

A general account of soft radiation observed on cosmic ray balloon flights appeared in *Bulletin No. 10.* Results obtained by J. L. Winckler and L. Peterson of the University of Minnesota and by K. A. Anderson of the State University of Iowa were reported, and a flight on August 29–30, 1957, under the supervision of Anderson was described.

X-rays: In an additional flight conducted by Anderson on September 1–2, 1957, an X-ray shower not associated with a magnetic storm, as in the August 29–30 event, was observed. The radiation was present even before the balloon reached ceiling altitude, at 1420 UT, and was still detectable 12 hours later. After some early time variations, the radiation slowly diminished in a roughly linear fashion. The ion-chamber to single-counter ratio changed very markedly (more than threefold) during the flight, particularly during the first hour after ceiling altitude was reached. The ratio became so high at times that there appeared to be no way to attribute the radiation to X-rays. During the greater part of the event the ratio was characteristic of 100-kev X-rays, although ratio evaluation becomes inaccurate as the X-ray intensity diminishes.

It was established on several night flights made while the regularly appearing auroral forms were present that these forms contributed a small quantity of soft radiation at the altitude of the balloon.

The University of Minnesota workers estimate that the current of high-energy electrons producing the X-rays in the Minneapolis experiments described in *Bulletin No. 10* is at least 3×10^6 electrons/cm^2/sec, and probably an order of magnitude greater. It is, therefore, approximately equal to auroral proton fluxes and to the fluxes observed in soft radiation at rocket heights. The X-ray bursts usually appear when a homogeneous auroral arc develops a

strong ray structure, or when rays increase in intensity.

X-ray bursts were also observed during the auroral storm of February 10–11. These showed a strong correlation with large magnetic bays (increases or decreases in intensity of magnetic-field components, recorded as bay-like indentations in the graph of intensity variations with time) observed at Fredericksburg Observatory and with cosmic-noise absorption in the ionosphere observed at Boulder, Colorado. X-ray bombardment in the daytime was observed on several other occasions during sudden intensity decreases in cosmic radiation accompanied by increased geomagnetic activity. However, no auroral correlation was possible.

Solar Gamma Rays: During a balloon flight in Cuba, a strong burst of what are believed to be solar gamma rays was observed by the University of Minnesota investigators coincident with a solar flare. The burst lasted 18 seconds and was also exactly coincident with a strong radio-noise burst. The energy of the gamma radiation was estimated at 0.5 mev. The investigators believe it may have arisen from nuclear processes excited during the flare, since it is difficult to account for by more usual mechanisms.

Latitude Effect: The remarkable latitude effect reported in *Bulletin No. 3,* in which changes of cosmic ray intensity could be detected within a latitude change of as little as seven miles at Minneapolis in the fall of 1956, has now vanished owing to the removal of low-energy particles from the cosmic ray spectrum during the solar maximum in 1957–1958. At present, no change with latitude is detectable. A large effect is still detectable at Texas, as the

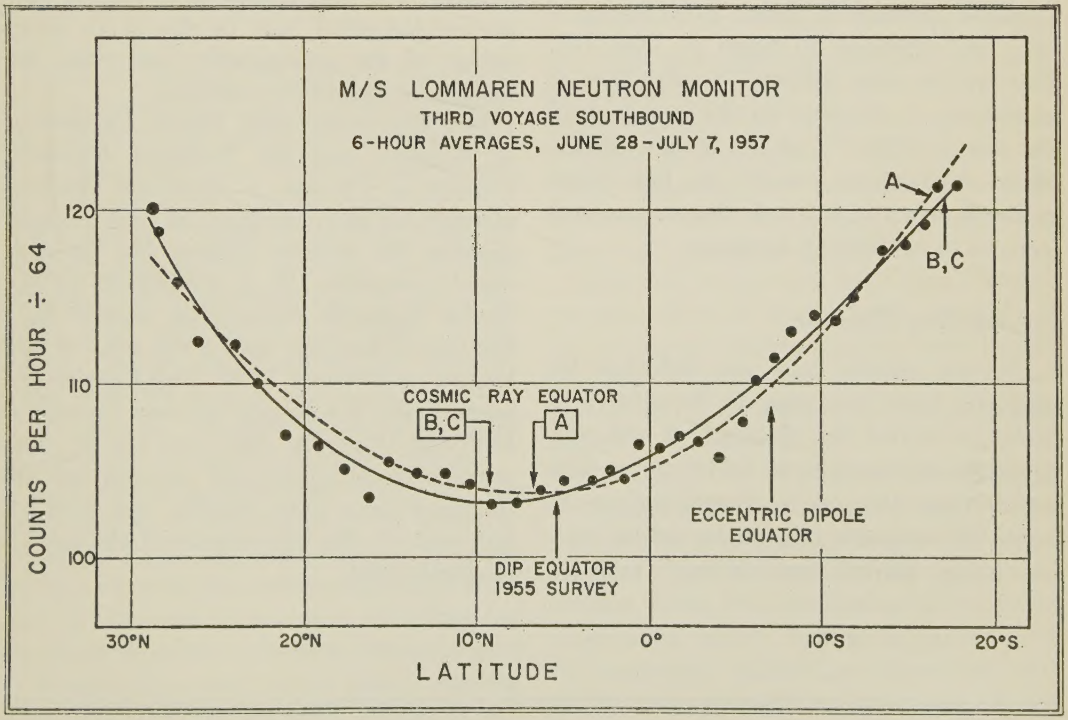

Fig. 6. *Typical Set of Data Used to Locate the Cosmic Ray Equator (line of minimum cosmic ray intensity). A, B, and C are analytical curves of successively higher order fitted to the data by the least-squares method to provide a smooth variation through the experimental points. (Although they represent second- and third-order mathematical terms, respectively, curves B and C are identical.)*

energies still present in the primary spectrum are latitude-sensitive at that location.

Rapid Fluctuations: The cosmic ray monitoring program in general shows many fluctuations of the primary radiation at 100,000 ft which are well correlated with fluctuations observed at sea level by neutron monitors and by ion chambers.

Balloon experiments were conducted by J. J. Corrigan, S. F. Singer, and M. J. Swetnick, of the University of Maryland, to detect rapid fluctuations in the low-energy component of cosmic rays and to detect small solar-flare effects. A high-counting-rate Geiger telescope was flown in an aircraft at altitudes of 25,000 to 45,000 ft at geomagnetic latitude 55°N.

No rapid fluctuations were observed on a flight on August 8, 1957, but at 1349 UT, August 9, while the balloon was flying at 25,000 ft, an increase of about 30% began. It lasted about 2.7 min. At the same altitude, a second increase of about 30%, lasting 2 min, was observed to begin at 1433 UT. The first increase followed a solar flare of importance 1, observed on the west limb of the sun at 1330 UT, about 20 min earlier. These observations provide the first direct evidence for a small, solar-flare-associated increase in cosmic ray intensity.

Cosmic Ray Equator

Because cosmic rays are deflected by magnetic fields they may be thought of as probes to reveal the distribution and configuration of the magnetic field in the regions surrounding the earth. Investigations to locate the magnetic equator for cosmic rays are being carried out through multiple crossings of the equatorial region by ships and aircraft.

Investigation of the location of the magnetic equator for cosmic ray particles, under the supervision of J. A. Simpson, University of Chicago, was begun with the USS *Atka* and by three round-the-world Antarctic expeditions of the USS *Arneb*. The ships carried cosmic ray neutron monitors back and forth across the equator. In addition, twelve equatorial crossings were carried out within a short time interval by high-flying aircraft fitted with neutron detectors.

As a result of these investigations, a 25% variation of maxima with longitude was determined for the first time. Also, results show that the magnetic center of the earth for cosmic ray particles is about 45° west of the magnetic center derived from spherical harmonic analysis of geomagnetic data. The cosmic ray equator was found to lie close to, but west of, the surface magnetic-field dip equator. The shift is such as to suggest that part of the effect may be due to an interaction of the geomagnetic field with the ionized interplanetary medium.

In collaboration with Upsala University, of Sweden, and the National Research Council of Canada, a shipboard neutron monitor has been operated on four voyages crossing the equator aboard the Swedish vessel *Lommaren*. M. A. Pomerantz of the Bartol Research Foundation reports that from these data the cosmic ray equator was located at 8°N and 14°W. This location apparently did not change between November 1956 and December 1957 (see Fig. 6). The position of the cosmic ray equator as determined from these results, lies close to, but west of, the dip equator of the earth's magnetic field.

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